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Subject: Planetary Protection Provisions for Robotic Extraterrestrial Missions

Responsible Office: Science Mission Directorate

Appendix A. Detailed Planetary Protection Requirements

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A.1 Category-Specific Listing of Target Body/Mission Types (advisory only)

a. Category I: Flyby, Orbiter, Lander: the Earth's Moon; Mercury; Undifferentiated, Metamorphosed Asteroids; others TBD pending National Research Council or other-source recommendations.

b. Category II: Flyby, Orbiter, Lander: Venus; Jupiter (exclusive of its icy moons); Saturn; Titan; Uranus; Neptune; Triton; Pluto/Charon; Kuiper-Belt objects; Comets; Carbonaceous Chondrite Asteroids; others TBD pending National Research Council or other-source recommendations.

c. Category III: Flyby, Orbiter: Mars; Europa; Ganymede; Callisto; others TBD pending National Research Council or other-source recommendations.

d. Category IV: Lander, Probe: Mars; Europa; Ganymede; Callisto; others TBD pending National Research Council or other-source recommendations.

e. Category V: Any Earth-return mission.
"Unrestricted Earth return": the Earth's Moon; Undifferentiated, Metamorphosed Asteroids; Short-period Comets; Solar Wind; others TBD (see 2.2.5).
"Restricted Earth return": Mars, Europa; others TBD (see 2.2.5).

A. 2 Category III/IV/V Requirements for Mars

A.2.1 Category III (Mars Orbiters).

a. Orbiter spacecraft that achieve microbial burden levels (surface, mated, and encapsulated) defined in the specification "Maximum Total Microbial Spore Burden for Category III Missions to Mars" shall not be required to meet impact or orbital lifetime requirements. The microbial burden level requirement for Mars is noted in the specification sheet "Maximum Total Microbial Spore Burden for Category III Missions to Mars." Achievement of these levels will likely require some form of active microbial reduction. Approved bioassays (see NPR 5340.1) are required to establish the microbial burden levels. Assembled spacecraft and all modules that have been bioassayed must be protected against recontamination.

b. Orbiter spacecraft that do not meet the requirements, "Maximum Total Microbial Spore Burden for Category III Missions to Mars," are required to meet a probability of impact requirement of 10-2 for a specified orbital lifetime limit, as noted in the specification "Orbital Lifetime Probability, Mars." Mission compliance with these

requirements will consist of probability-of-impact analysis and orbital lifetime analysis. Trajectory biasing may be employed to lower the probability-of-impact of mission hardware, but is not required.

c. For Orbiters that meet orbital lifetime requirements, biological cleanliness is assumed by the use of ISO Class 8 (or Class 100,000 under Fed. Std 209E) cleanrooms and the associated procedures. No additional bioload quantification is generally necessary.

A.2.2 Category IV (Mars Landers)

For Mars Landers, Category IV is subdivided into IVa, IVb, and IVc:

a. Category IVa missions comprise lander systems not carrying instruments for the investigation of extant Martian life. These lander systems are restricted to a total surface microbial burden no greater than Viking lander preterminal sterilization levels (see specification sheet "Maximum Surface Microbial Spore Burden for Category IVa Missions to Mars").

b. Category IVb missions comprise lander systems carrying instruments designed to investigate extant Martian life. For such missions, the following requirements apply:

1. Either the entire landed system must be sterilized to the microbial burden levels defined in the specification sheet "Maximum Surface Microbial Spore Burden for Category IVb and IVc Missions to Mars," or to levels driven by the nature and sensitivity of the particular life-detection experiments, whichever are more stringent.

2. Or the subsystems that are involved in the acquisition, delivery, and analysis of samples used for life detection must be sterilized to burden levels defined in the specification sheet "Maximum Surface Microbial Spore Burden for Category IVb and IVc Missions to Mars" and a method of preventing recontamination of the sterilized subsystems and the contamination of the material to be analyzed is in place.

c. Category IVc missions comprise lander systems that investigate Martian special regions (see definition below). For such missions, whether or not they include life detection experiments, the following requirements apply:

1. Case 1. If the landing site is within the special region, the entire landed system shall be sterilized at least to the burden levels defined in the specification sheet "Maximum Surface Microbial Spore Burden for Category IVb and IVc Missions to Mars."

2. Case 2. If the special region is accessed through horizontal or vertical mobility, either the entire landed system shall be sterilized to the microbial burden levels defined in the specification sheet "Maximum Surface Microbial Spore Burden for Category IVb and IVc Missions to Mars," or the subsystems that directly contact the special region shall be sterilized to these levels and a method of preventing their recontamination prior to accessing the special region shall be provided.

   If an off-nominal condition (such as a hard landing) would cause high probability of inadvertent biological contamination of the special region by the spacecraft, the entire landed system must be sterilized to the Viking post-terminal sterilization microbial burden levels.

A.2.2.1 Definition of a "Special Region"

A Special Region is defined as a region within which terrestrial organisms are likely to propagate or a region which is interpreted to have a high potential for the existence of extant Martian life forms. Given current understanding, this applies to regions where liquid water is present or may occur. Specific examples include but are not limited to:

a. Subsurface access in an area and to a depth where the presence of liquid water is probable.

b. Penetrations into polar caps, or other regions of significant water ice.

c. Areas of hydrothermal activity.

For all subcategories (IVa, IVb, and IVc), the following apply:

1. Achieving the prescribed levels of cleanliness will require contamination control (minimum ISO Class 8, or Class 100,000 under Fed. Std 209E, assembly and attendant procedures), microbiological assays, and maintenance of hardware cleanliness. Contamination control effectiveness must be monitored and demonstrated by periodic assays. These assays must also be employed to determine the hardware microbial burden.

2. When needed to meet the burden requirement specifications, the project must provide the facility and the means to accomplish any required microbial reduction. The facility will be subject to certification and the means of microbial reduction subject to approval and monitoring by the PPO.

3. Dry heat is the approved microbial reduction method, and specifications for its use are provided in Appendix B. Alternative methods may later be certified for this purpose, but they will require a demonstration of effectiveness by the project and the approval of the PPO. Following the final predecontamination (or presterilization) microbiological assays and the microbial reduction procedure (as required), the project must demonstrate that the spacecraft or subsystem(s) are adequately protected against recontamination. This may require the use of a bioshield or shroud. Whatever the means of protection, the project must provide evidence that decontamination requirements are not compromised following terminal treatment.
4. An organics archive is required of the bulk (>1kg) organic constituents of all launched hardware which is intended to directly contact the target planet or which might accidentally do so. Each flight program office will provide for the collection and storage, for at least 20 years from the launch of the spacecraft, of a 50 g sample of each organic compound whose total amount in a planetary landing system exceeds 25 kg.

A.2.3 Category V (Sample Return Missions from Mars)

The Earth-return mission is classified "Restricted Earth return" and is subject to the following requirements:

a. Unless specifically exempted, the outbound leg of the mission shall meet Category IVb requirements. This provision is intended to avoid "false positive" indications in a life-detection and hazard-determination protocol or in the search for life in the sample after it is returned. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all subsequent Mars missions.
b. Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container must be sealed after sample acquisition. A redundant, fail-safe containment procedure with a method for verification of its operation before Earth-return shall be required. For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.
c. The mission and the spacecraft design must provide a method to "break the chain of contact" with Mars. No uncontained hardware that contacted Mars, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the Mars environment shall be provided during sample container loading into the containment system, launch from Mars, and any in-flight transfer operations required by the mission.
d. Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving Mars for return to Earth; and 3) prior to commitment to Earth entry.
e. For unsterilized samples returned to Earth, a program of life detection and biohazard testing or a proven sterilization process shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

A.3 Category III/IV/V Requirements For Europa

A.3.1 Category III/IV (Europa Orbiters and Landers).

Requirements for Europa flyby, orbiter, or lander missions, including microbial reduction, shall be applied in order to reduce the probability of inadvertent contamination of an Europan ocean to less than 1x10-4 per mission. These requirements will be refined in future years, but the calculation of this probability should include a conservative estimate of poorly known parameters and address the following factors, at a minimum:

a. Microbial burden at launch.
b. Cruise survival for contaminating organisms.
c. Organism survival in the radiation environment adjacent to Europa.
d. Probability of landing on Europa.
e. The mechanisms of transport to the Europan subsurface.
f. Organism survival and proliferation before, during, and after subsurface transfer.

Preliminary calculations of the probability of contamination suggest that microbial reduction will likely be necessary for Europa orbiters as well as for landers. This will require the use of cleanroom technology, the cleanliness of all parts before assembly, and the monitoring of spacecraft assembly facilities to understand the bioload and its microbial diversity, including specific problematic species. Specific methods should be developed to eradicate problematic species. Methods of microbial reduction should reflect the type of environments found on Europa, focusing on Earth extremophiles most likely to survive on Europa, such as cold and radiation tolerant organisms.

A.3.2 Category V (Sample Return Missions from Europa)

The Earth-return mission is classified, "Restricted Earth return" and is subject to the following requirements:

a. Unless specifically exempted, the outbound leg of the mission shall meet Category IVb requirements. This provision is intended to avoid "false positive" indications in a life-detection and hazard-determination protocol or in the search for life in the sample after it is returned. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all subsequent Europa missions.

b. Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container must be sealed after sample acquisition. A redundant, fail-safe containment procedure with a method for verification of its operation before Earth-return shall be required. For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.

c. The mission and the spacecraft design must provide a method to "break the chain of contact" with Europa. No uncontained hardware that contacted Europa, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the Europan environment shall be provided during sample container loading into the containment system, launch from Europa, and any in-flight transfer operations required by the mission.

d. Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving Europa for return to Earth; and 3) prior to commitment to Earth entry.

e. For unsterilized samples returned to Earth, a program of life detection and biohazard testing or a proven sterilization process shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

A.4 Requirements For Small Solar System Bodies

A.4.1 Outbound Categorization.

The small bodies of the solar system not elsewhere discussed in this document represent a very large class of objects. Forward contamination requirements for these missions are not warranted except on a case-by-case basis, so most such missions should adhere to Categories I or II requirements.

A.4.2 Sample Return Missions from Small Solar System Bodies

a. Determination as to whether a mission is classified "Restricted Earth return" or not (Category V) shall be undertaken with respect to the best multidisciplinary scientific advice, using the framework presented in the 1998 report of the U.S. National Research Council's Space Studies Board entitled, Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making (SSB 1998). Specifically, such a determination shall address the following six questions for each body intended to be sampled:

1. Does the preponderance of scientific evidence indicate that there was never liquid water in or on the target body?
2. Does the preponderance of scientific evidence indicate that metabolically useful energy sources were never present?
3. Does the preponderance of scientific evidence indicate that there was never sufficient organic matter (or CO2 or carbonates and an appropriate source of reducing equivalents) in or on the target body to support life?
4. Does the preponderance of scientific evidence indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperatures (i.e., >160 C)?
5. Does the preponderance of scientific evidence indicate that there is or was sufficient radiation for biological sterilization of terrestrial life forms?
6. Does the preponderance of scientific evidence indicate there has been a natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body?

   For containment procedures to be necessary ("Restricted Earth return"), an answer of "no" or "uncertain" must be returned to all six questions.

b. For missions determined to be Category V "Restricted Earth return" the following requirements shall be met:

1. Unless specifically exempted, the outbound phase of the mission shall meet contamination control requirements to avoid "false positive" indications in a life-detection and hazard-determination protocol, or in the search for life in the sample after it is returned.
2. Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container must be sealed after sample acquisition. A redundant, fail-safe containment with a method for

verification of its operation before Earth-return shall be required. For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.

3. The mission and the spacecraft design must provide a method to "break the chain of contact" with the small body. No uncontained hardware that contacted Europa, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the body's environment shall be provided during sample container loading into the containment system, launch from the body, and any in-flight transfer operations required by the mission.
4. Reviews and approval of the continuation of the flight mission shall be required at three stages: a) prior to launch from Earth; b) prior to leaving the body or its environment for return to Earth; and c) prior to commitment to Earth entry.
5. For unsterilized samples returned to Earth, a program of life detection and biohazard testing or a proven sterilization process shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

A.5 Additional Implementation Guidelines for Category V Missions

If during the course of a Category V mission there is a change in the circumstances that led to its classification, or a mission failure--e.g., new data or scientific opinion arise that would lead to the reclassification of a mission classified as "Unrestricted Earth return" to "Restricted Earth return," and safe return of the sample cannot be assured, or the sample containment system of a "Restricted Earth return" mission is thought to be compromised and sample sterilization is impossible--then the sample to be returned shall be abandoned. If the sample has already been collected, the spacecraft carrying it must not be allowed to return.

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